

# DOE DER Road Show

Clemson University

April 23, 2003

## Fuel Cell Technology Applications, Benefits & Perspectives



**LOGANEnergy**

[www.loganenergy.com](http://www.loganenergy.com)

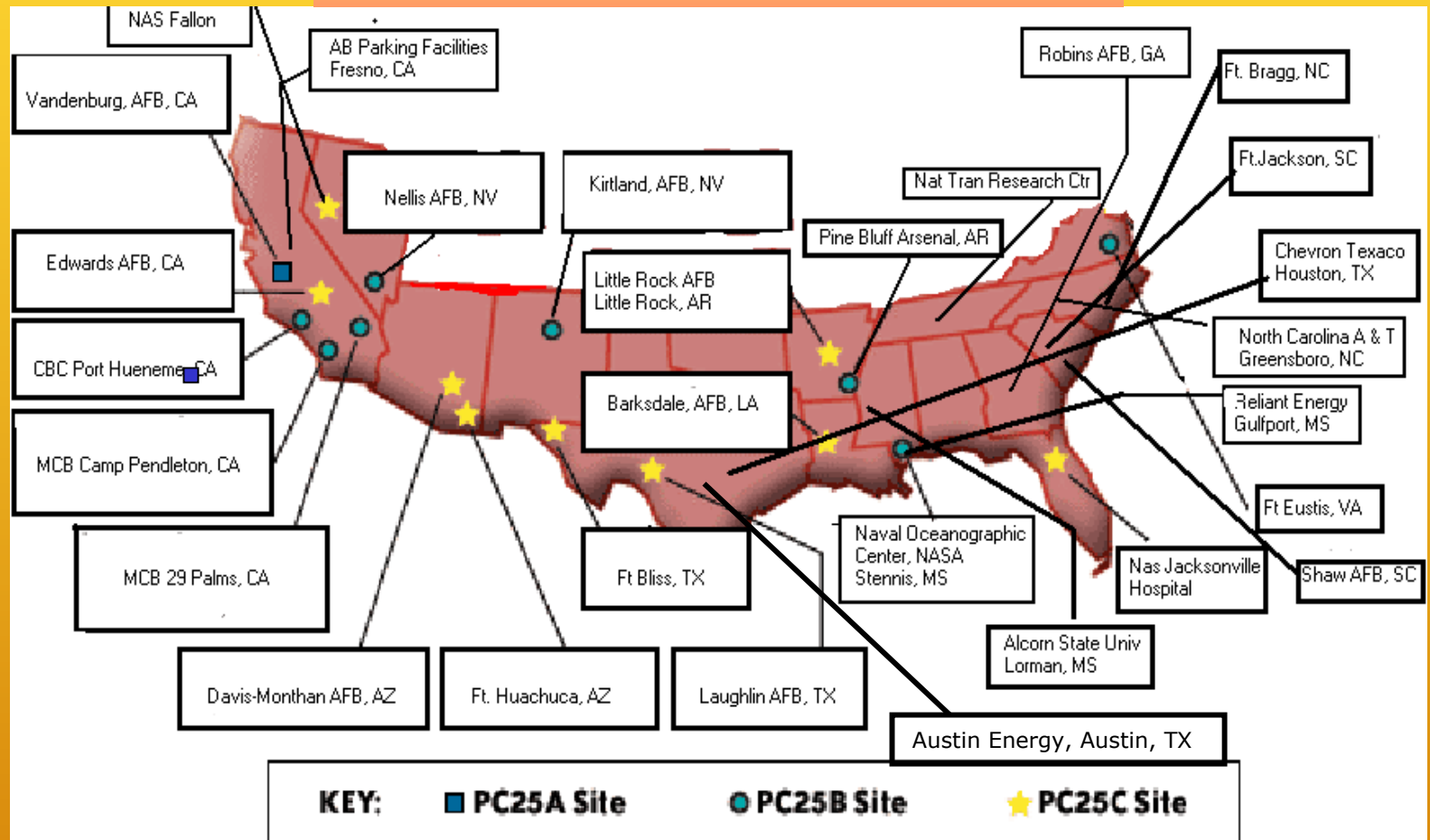
Samuel Logan, Jr.

# Technology ✧ Applications ✧ Benefits



# LOGAN Energy & Partners

## Nationwide Fuel Cell Project Experience



## Fuel Cell Energy Service Qualifications

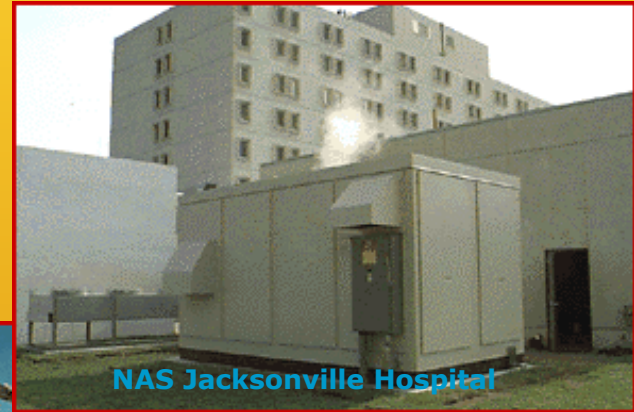
1. UTC Fuel Cells Product Representative
2. DOE Energy Performance Contractor
3. DOD Fuel Cell Contractor
4. UTC Authorized Fuel Cell Service Provider
5. CA Licensed Contractor
6. CPFA Qualified Fuel Cell Project Developer

# Installation Sites

1997-2002



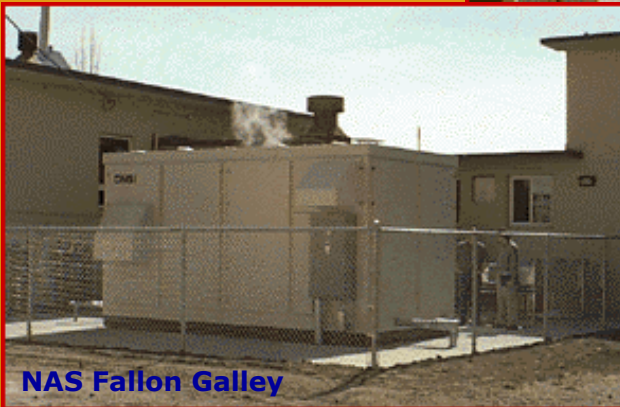
8th Air Force Hospital



NAS Jacksonville Hospital



Ft Huachuca Barracks



NAS Fallon Galley



Laughlin AFB Hospital

# FUEL CELL TECHNOLOGY

## Space and Defense



- 98 missions, 74,956 hours
- 3 powerplants per Orbiter
- 12 kW (21 kW max) each
- 2000 hour qualified life

### Orbiter Fuel Cell Power Plant



WCN 10464

WCN 8986

# FUEL CELL TECHNOLOGY

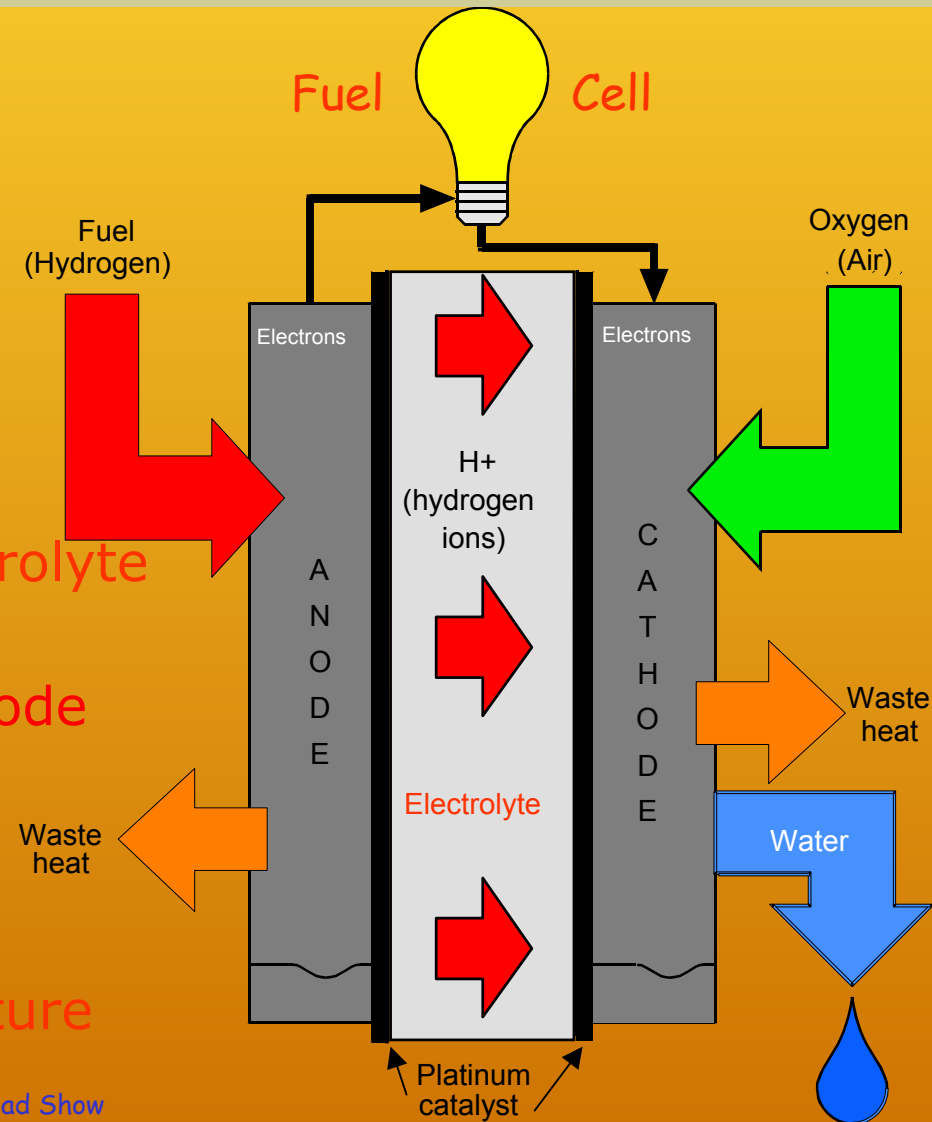
## Key Points:

- Direct Energy Conversion System,
- No Combustion, No Moving Parts,
- Electro-Chemical Process, Energy to Power,
- Continuous Hydrogen-Oxygen Reaction Dependent On Fuel Supply,
- May Be Hydrogen, Natural Gas, Propane, Other Methane Sources,
- Autonomous Operation, Low Maintenance, Minimal Pollution.

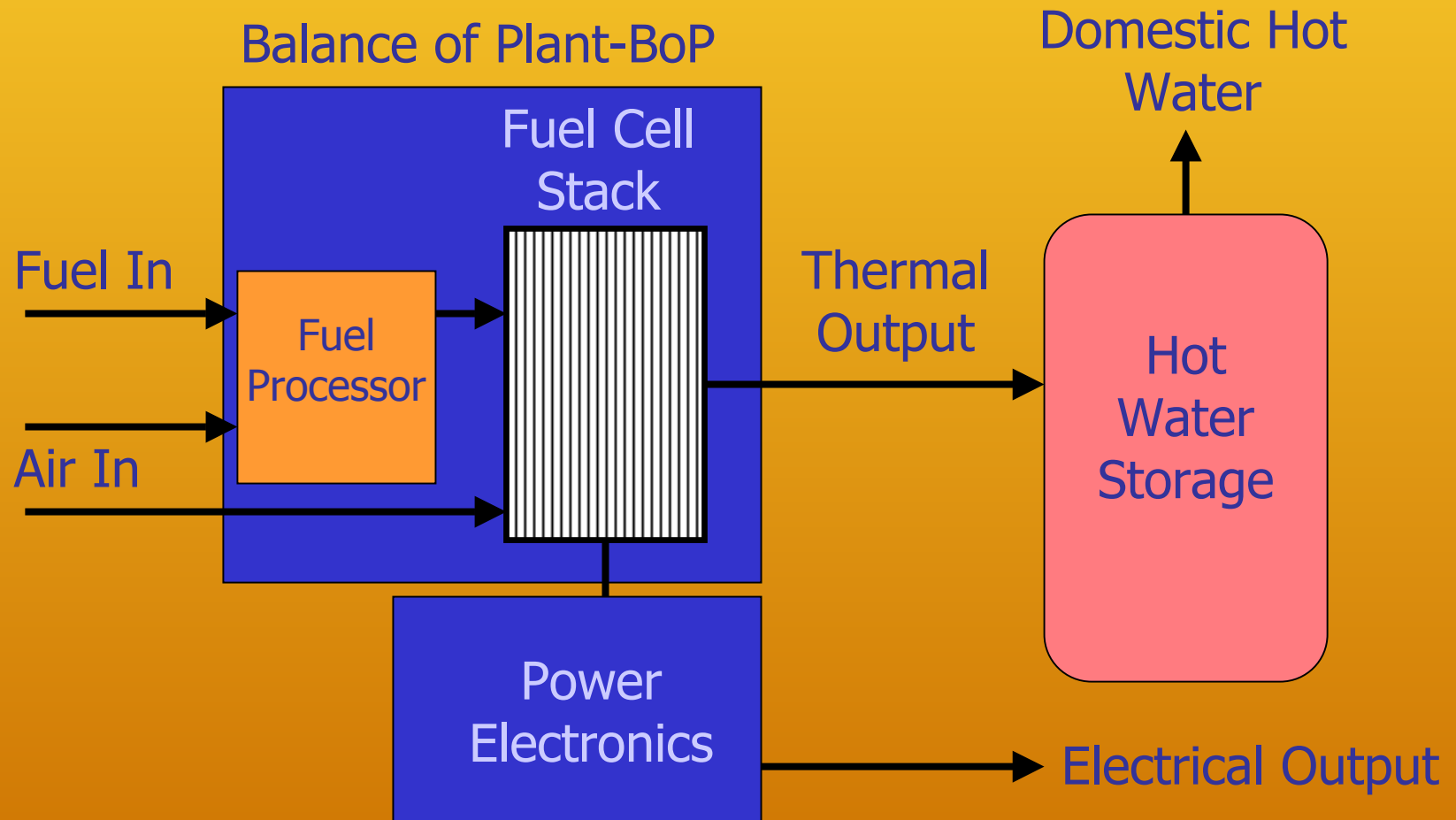


# What's a FUEL CELL

- ⚡ Electro-chemical reaction
- ⚡ Continuous  $H_2$  fuel flow
- ⚡  $H^-$  migration over conductor
- ⚡  $H^+$  penetration through electrolyte
- ⚡  $H^+ / H^-$  recombination at cathode
- ⚡ Heat &  $H_2O$  by-products
- ⚡ "Green" environmental signature

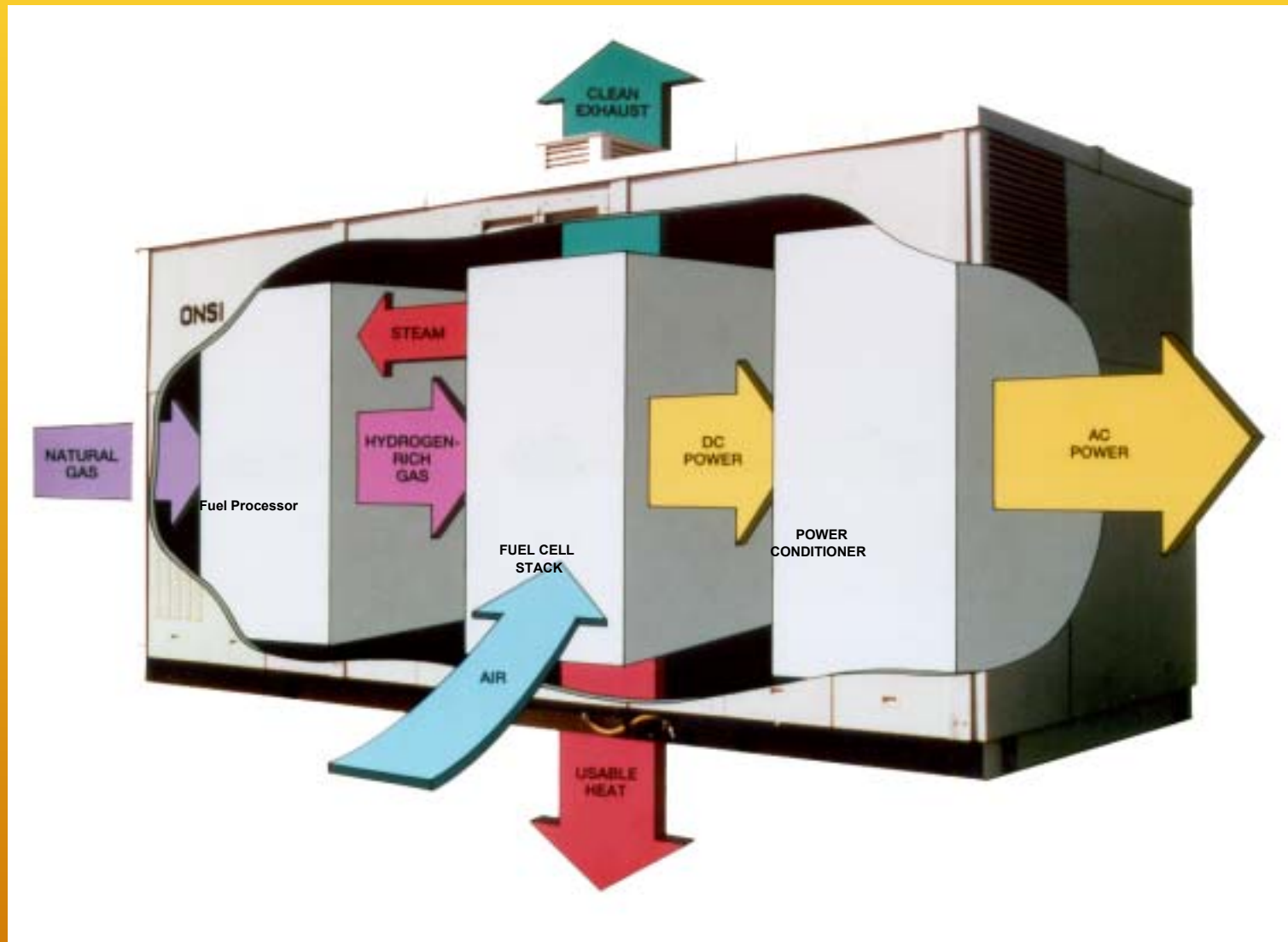


# What is a Fuel Cell System?





# FUEL CELL TECHNOLOGY



# Commercial Fuel Cell Specifications

<u>Characteristics</u>	<u>Standard Commercial System</u>	<u>Options</u>
<b>Electrical</b>	<ul style="list-style-type: none"><li>• 200k W/235KVA (-20 to 100F, up to 500 ft.)</li><li>- 480/277 Volt. 60 Hz</li><li>- 400/230 Volt. 50 Hz</li><li>• Grid-Connected</li></ul>	<ul style="list-style-type: none"><li>• Grid Independent Grid-Synchronized Single unit operation on dedicated circuits</li><li>- No overload capacity</li><li>• Dual Grid-Independent/ Grid-Connected</li></ul>
<b>Thermal Energy Available</b>	<ul style="list-style-type: none"><li>• &gt;700,000 Btu/hr @ 140~ F</li><li>- Single-Walled Hex</li></ul>	<ul style="list-style-type: none"><li>• &gt;700,000 Btu/hr @ 40~ F</li><li>- Double-Walled Hex</li><li>• High-Grade Heat</li></ul>
<b>Interfaces</b>	<ul style="list-style-type: none"><li>• Pipeline Natural Gas</li><li>• Make up City Water Requirement</li><li>• Facility Nitrogen Supply Required</li><li>• Simple Power Plant Control Panel With Interfaces For Diagnostics and Servicing</li></ul>	<ul style="list-style-type: none"><li>• ADG...LP Gas</li></ul>
<b>Power Plant Modules</b>	<ul style="list-style-type: none"><li>• Power Module</li><li>• Cooling Module</li></ul>	<ul style="list-style-type: none"><li>• Site cooling tower integration</li></ul>

# Types of Fuel Cells & Their Status

<u>Type</u>	<u>Electrolyte</u>	<u>Temperature</u>	<u>Status</u>
Solid Oxide	Ceramic	1800 °F	<ul style="list-style-type: none"> <li>● Proof-of-Concept.</li> </ul>
Molten Carbonate	Lithium-Potassium Carbonate	1200 °F	<ul style="list-style-type: none"> <li>● Large demonstration Complete.</li> <li>● Commercialization route difficult.</li> </ul>
Alkaline	Potassium Hydroxide	500 °F	<ul style="list-style-type: none"> <li>● Apollo, Space Shuttle</li> <li>● Needs pure H<sub>2</sub></li> </ul>
Phosphoric Acid	Silicon Carbide w H <sub>2</sub> PO <sub>4</sub>	350 °F	<ul style="list-style-type: none"> <li>● "Commercial" many applications.</li> </ul>
PEM	Plastic membrane	180 °F	<ul style="list-style-type: none"> <li>● Residential Application</li> </ul> <p>Automotive market could help significantly!</p>

## What are Codes and Standards?

- Documents that establish a basis for technical communication
- Provisions for assessing technology safety and performance
- The basis for Building Construction Regulations or other rules addressing public health and life-safety

# Why Have Codes and Standards?

## Codes and Standards can support fuel cells

- reduce expenditure of manpower
- save time and money
- enhance technology marketing and deployment
- facilitate a manufacturing and servicing infrastructure
- realize multi-lateral approvals and international trade
- secure technology benefits
- protect the market from unsafe products, and
- shoddy unsafe installation practices
- allow for simpler testing and certification of products

# Organizations Directly Involved in Fuel Cells

Development, adoption, implementation and enforcement by:

- ICC International Codes
- NEC 2002
- NFPA Standards
- ASME Standards
- IEEE Standards
- UL Standards
- IEC and ISO Standards
- [http://www.hydrogensafety.info/articles/H\\_C&S\\_Matrix\\_20May02.PDF](http://www.hydrogensafety.info/articles/H_C&S_Matrix_20May02.PDF)

# U.S. Codes and Standards for Fuel Cells



## ANSI Z 21.83-1998/CSA

### 12.10 Fuel Cell Power Plants

#### *Construction*

- Materials
- General construction and assembly
- Enclosures and associated construction
- Air/fluid handling and moving equipment
- Electrical equipment and wiring
- Protection of service personnel
- Safety circuit analysis
- Instructions and marking Heaters and vessels
- Piping systems
- Drain, venting, and ventilation exhaust systems
- Automatic ignition systems and gas-air control
- Flame safeguards
- Fuel gas controls and equipment



# U.S. Codes and Standards for Fuel Cells



## ANSI Z 21.83-1998/CSA 12.10

### Fuel Cell Power Plants

#### *Performance*

- ultimate strength
- allowable leakage
- protection
- emissions
- burner operation
- automatic ignition
- exhaust gas and surface and component temperatures
- electrical tests
- rain and wind tests
- adhesion/legibility of markings

# U.S. Codes and Standards for Fuel Cells



## NFPA 853 Standard for Stationary Fuel Cell Power Plants, 2003 Edition

Design, construction, and installation of stationary (non-portable) fuel cell power plants (of all sizes...formerly < 50kW):

- (1) A singular prepackaged, self-contained power plant unit
- (2) Any combination of prepackaged, self-contained power plant units
- (3) Power plant units comprised of two or more factory matched modular components intended to be assembled in the field and
- (4) Engineered and field-constructed power plants that employ fuel cells

See Draft of NFPA 853 at

[http://www.nfpa.org/Codes/NFPA\\_Codes\\_and\\_Standards/List\\_of\\_NFPA\\_documents/NFPA\\_853.asp](http://www.nfpa.org/Codes/NFPA_Codes_and_Standards/List_of_NFPA_documents/NFPA_853.asp)



# NES Evaluation Protocol for Stationary FC Power Plants

- Undertaken on behalf of U.S. DOE (PNNL)
- Input from FC developers, manufacturers, research & testing labs, engineers, regulators, utilities, etc.
- Basis for evaluation and assessment of stationary FC units intended for building applications
- Advises manufacturers of testing/documentation needed for building regulatory acceptance
- Voluntary and advisory program of evaluation
- National Evaluation Reports...see Fuel Cell Evaluation Report  
[http://www.nateval.org/html/protocols/fc\\_protocol\\_apr\\_17\\_01.pdf](http://www.nateval.org/html/protocols/fc_protocol_apr_17_01.pdf)

# ASME Performance Test Code (PTC) 50

## Codify Fuel Cell Industry Standards & Power System Performance

- Objective Consistency Within the Industry
- Definitions and Descriptions of Terms
- Guiding Principles, Performance Testing
- Instruments and Methods of Measurement
- Calculations and Results
- Report of Comparative Results
- Eliminate Uncertainty

# IEEE Interconnection Standard P1547

- ***Title:*** Standard for Interconnecting Distributed Resources with Electric Power Systems
- ***Purpose:*** Provide a uniform standard for interconnection of distributed resources with electric power systems, and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection
- Sept. 2002, Final Adoption very likely but still being balloted!

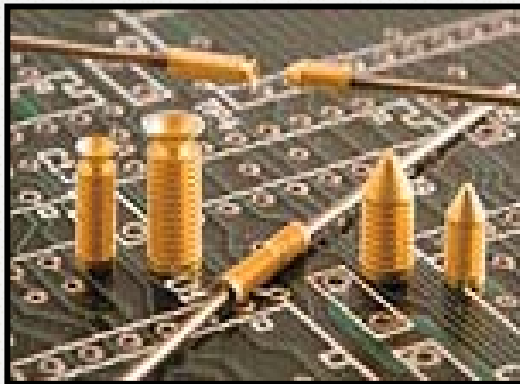
# Underwriters Laboratories

## UL 1741 Static Inverters and Charge Controllers

- Scope includes all static inverters, converters, and equipment controllers with or without grid connect
  - Will cover all distributed generation technologies
  - New title and scope inaugurated 01/01/01 with public comment availability until Sept 2002
- 
- UL 2200 Stationary Engine Generator Assemblies
  - UL 674 Electric Motors and Generators for Hazardous (Classified) Locations
  - UL 1778 Uninterruptable Power Supply Equipment

## Applications... Premium Power

- ⚡ Multiple "9s" of Availability
- ⚡ Premium Power for Technology Loads
- ⚡ Assured Power for Mission Critical Loads







## Applications... Premium Power

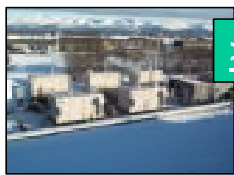
### Assured Power Fuel Cell Systems



> 0.9999

976F8

- 1 PC25C; Fuel Cell Primary; Grid back-up to fuel cell
- **Seamless Transfer (<1/4 cycle)**



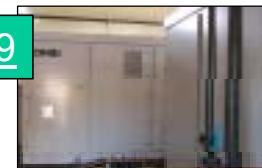
>0.9999

CA0479

- 5 PC25C's; Grid parallel operation; 4 of 5 fuel cells required to support critical load
- **Seamless Transfer (<1/4 cycle)**

- 2 PC25C's; Grid parallel operation; 1 fuel cell required to support critical load
- **Motorized Switch**

>0.99999



CA0628A

- 4 PC25C's; 100% fuel cell redundancy; dual gas/electric feeds; redundant rotary UPS/flywheels/diesels; Grid backup
- **Seamless Transfer (<1/4 cycle)**

>0.999999



1488-1

Sure Power™ System

**Utility grid ~.999 availability**

00384-PPT  
002109

## Applications... Assured Power



**Omaha National Bank**



**USPO Anchorage AK**



## Applications... Commercial Power

### 4 Times Square, New York, NY

- Benefits
  - Low emissions
  - High efficiency
  - Low noise
  - Increased flexibility under EPA Title 5
  - Potential tax credits
- Typical locations
  - Office buildings
  - Universities
  - Government buildings



© 2000 Andrew Gordon

CA0517

4 Times Square, NYC, NY

PPT00052  
R000108



## Applications...

### Distributed Power

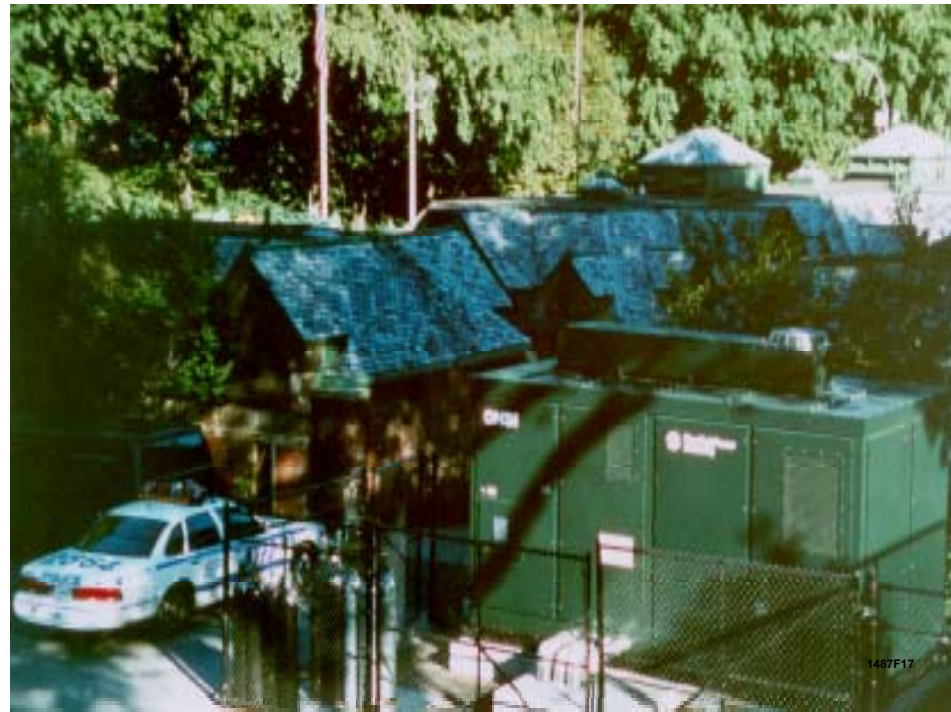
## Central Park Police Station, New York, NY

### Benefits

- Meet customer needs when:
  - Poor or no grid
  - Modular for growth
- Avoid grid construction
- Grid independence
- Operational control of power source

### Typical locations

- End of electric grid
- Undersized grid
- No grid





## Applications... Renewable Energy

### Las Virgenes Municipal Water District Calabasas, California

#### 2 PC25 Power Plants



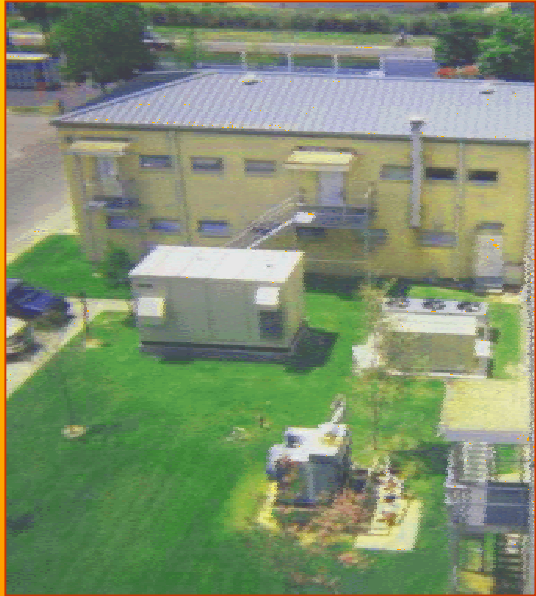
CA63



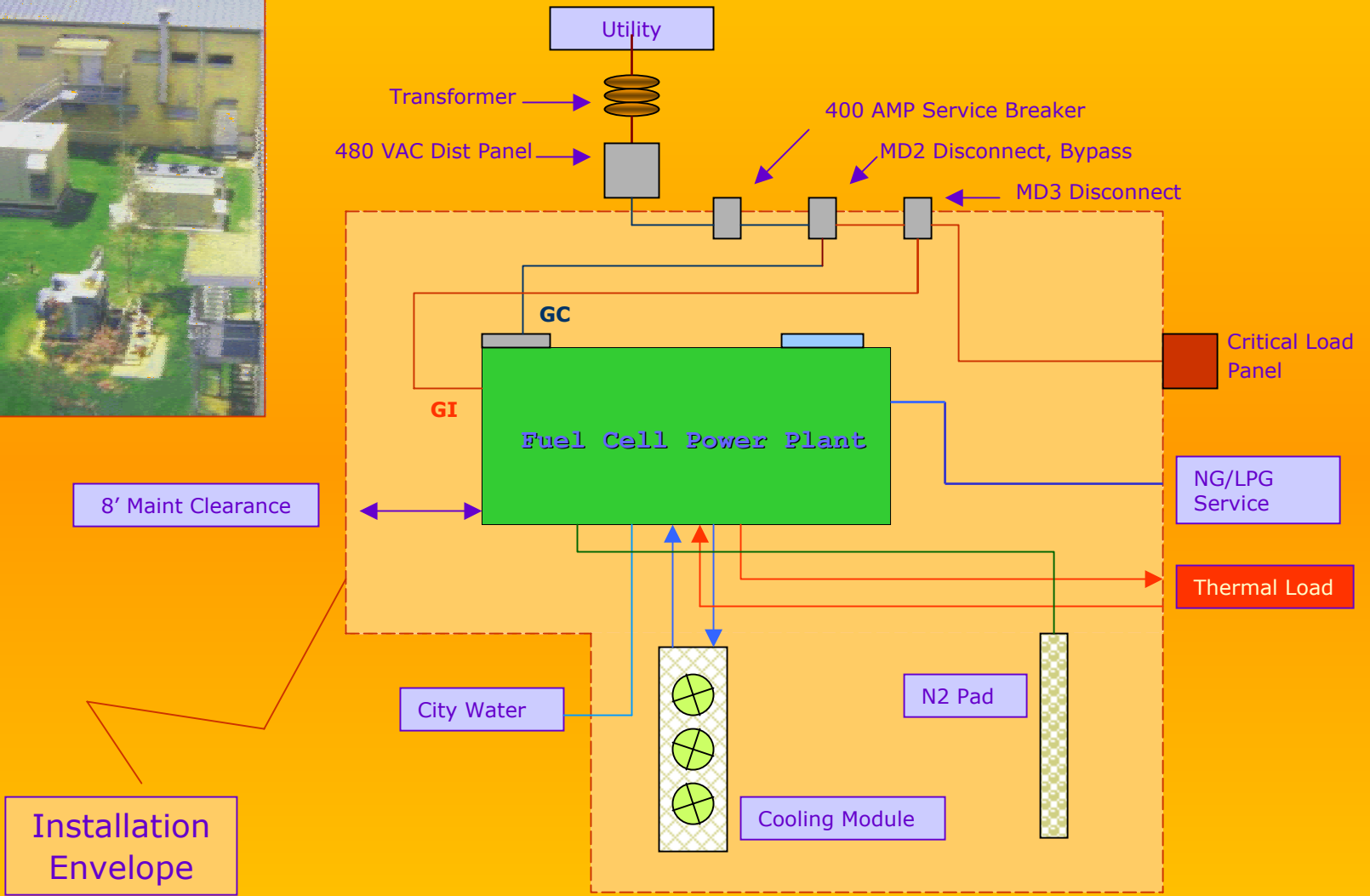
CA0629

- 50% Methane
- 200-1500ppm H<sub>2</sub>S
- <1ppm NO<sub>x</sub> SO<sub>x</sub> CO
- 900,000 btuh





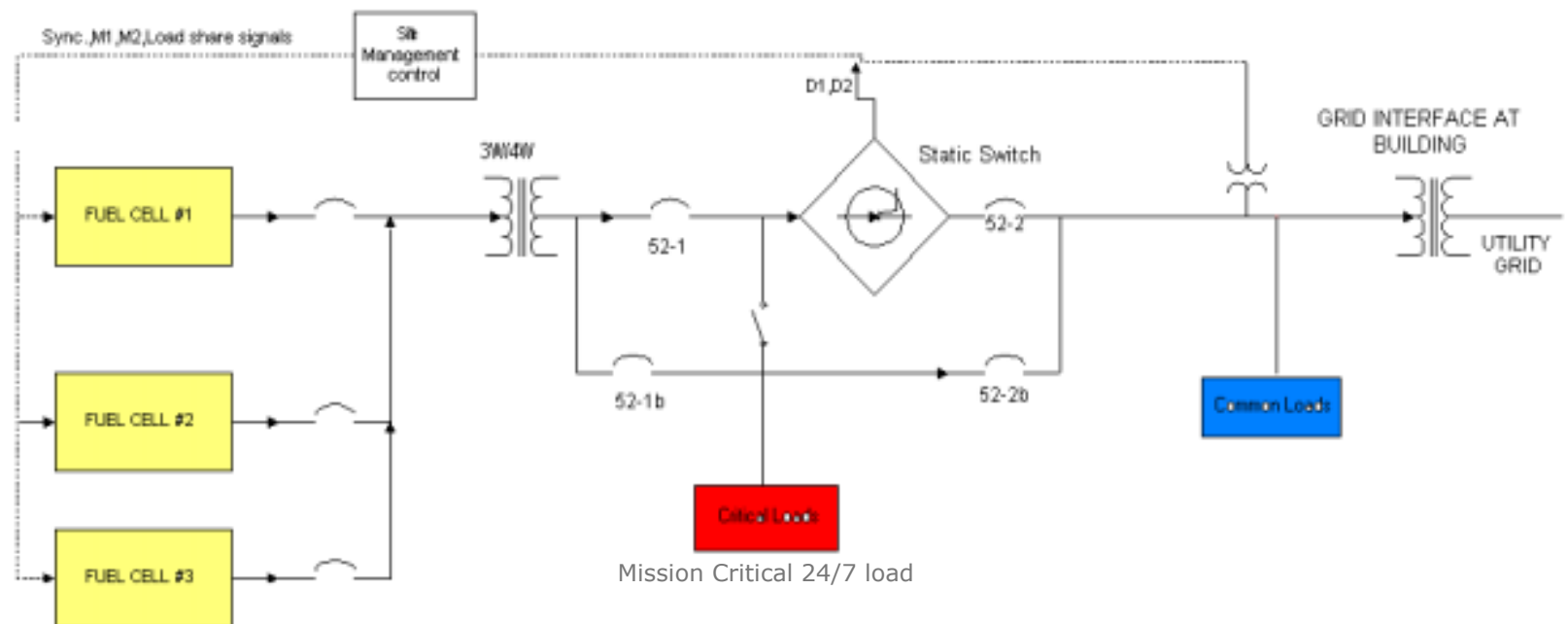
# Applications... Typical Site Layout



# Applications...

## Multi Unit Layout

### FUEL CELL -MULTI-UNIT LOAD SHARE WITH STATIC SWITCH







## Premium Applications... Summary



“Where computers, telecommunications equipment, electronic security systems, or other electronic control systems demand a noise-free, highly reliable, high quality electric energy source”.



“Where critical electrical loads require a continuous, uninterrupted electric energy source”.

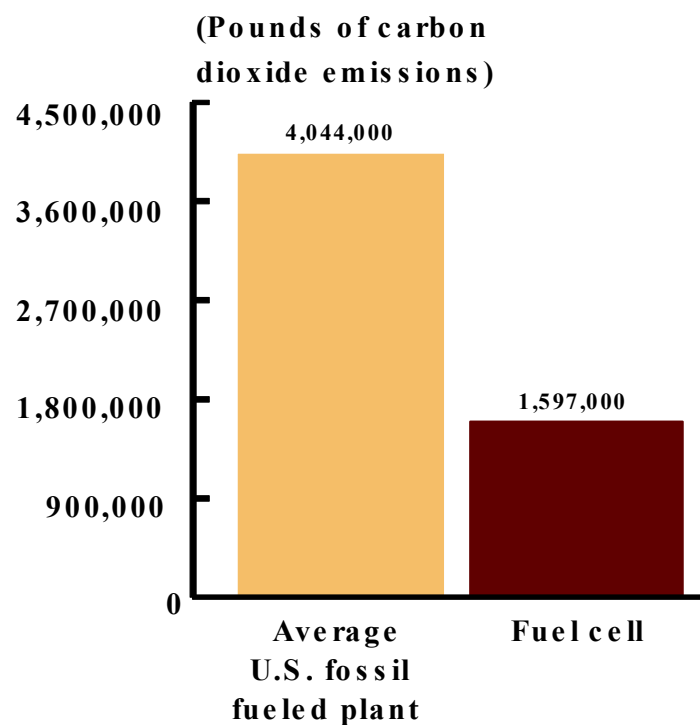
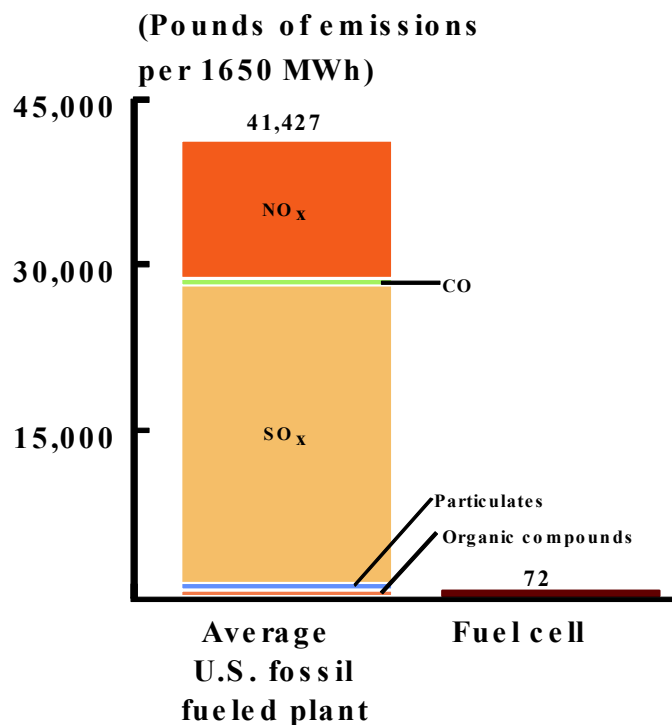


“Where critical electrical loads are currently being supplied by high-cost uninterruptible power supplies, motor generator sets, or backup generators running on fossil fuels”.



## Benefits... Green Power

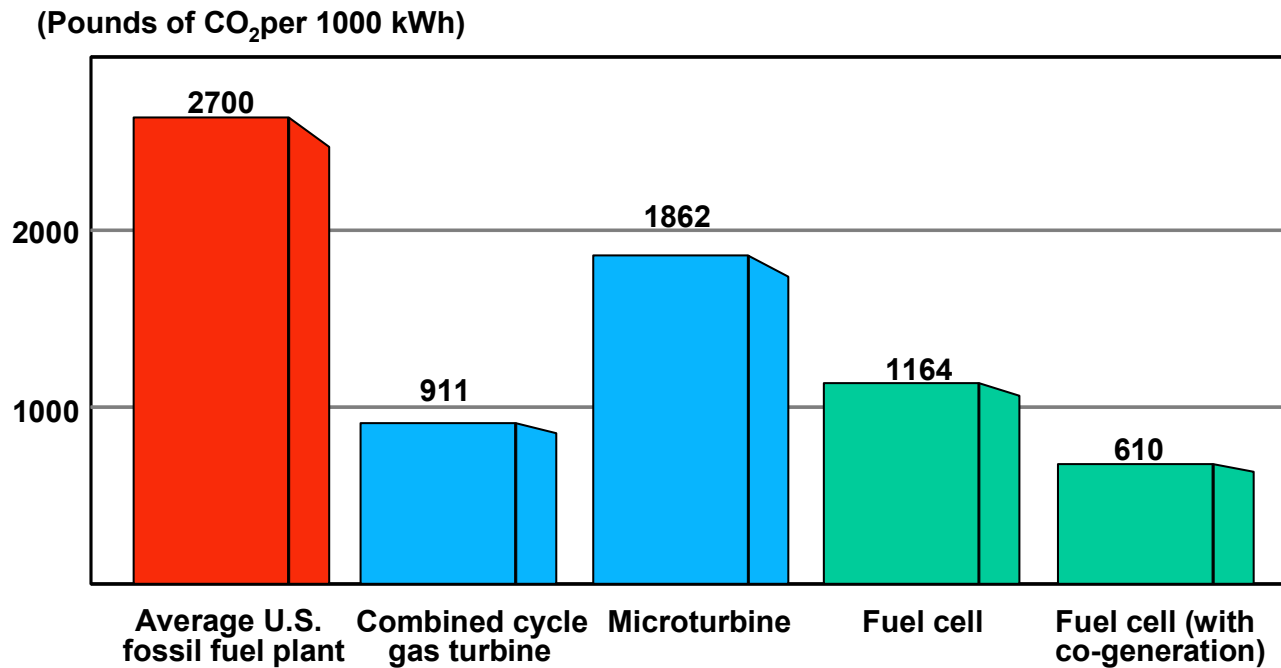
### Fuel Cell Air Emissions PC25 emissions from one year of operation vs. average U.S. fossil fuel plant





## Benefits... Lowest Emissions

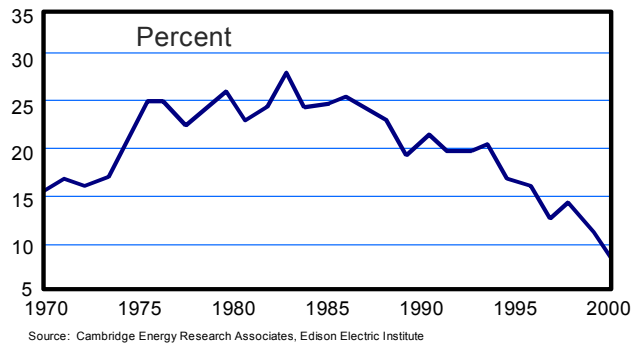
### CO<sub>2</sub> Emissions



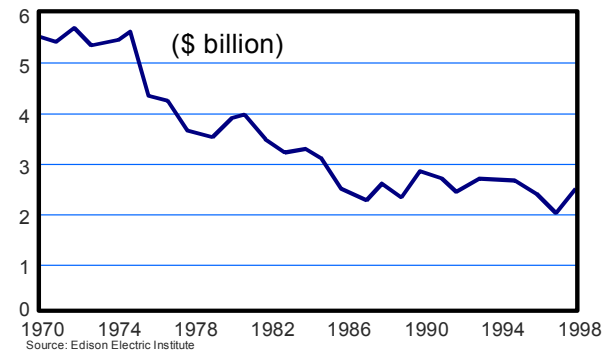


## Benefits... Distributed Power

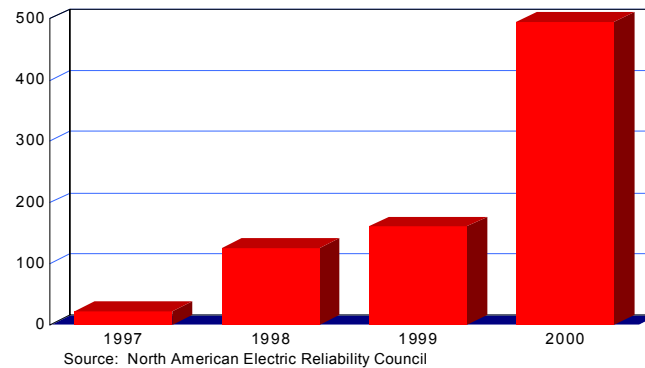
### Distributed Generation Impetus Infrastructure Decay



Capacity Margin



Transmission Investment



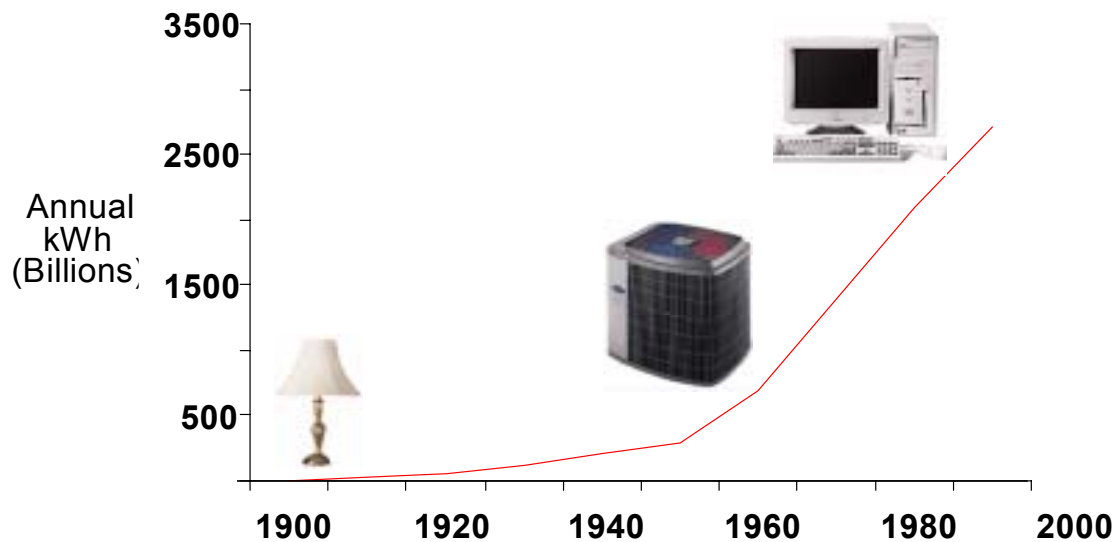
System Disruptions

PPT-01288  
010703



## Benefits... Distributed Power

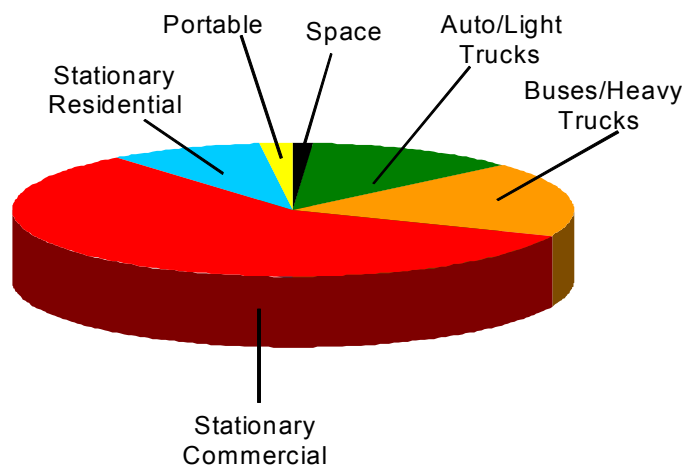
### Distributed Generation Impetus New Growth From Demanding Loads



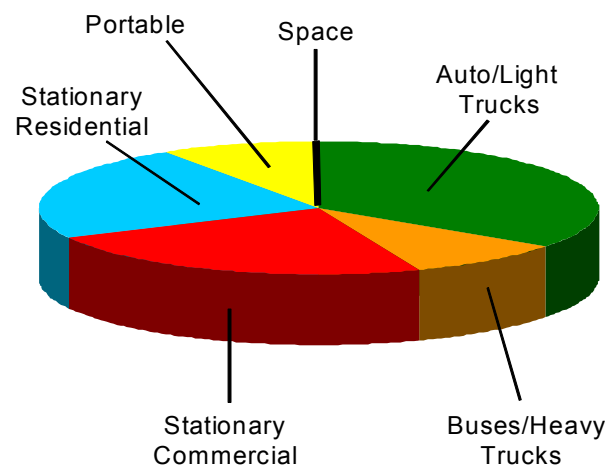
PPT-01291  
010703



## Projected... Market Orientation



2005  
\$1 Billion



2010  
\$20 Billion

# FUEL CELL PRODUCTS



Westinghouse Solid Oxide



2 MW Santa Clara, Molten Carbonate  
Fuel Cell Energy Co.



Alkaline UTC



NRECA Transportable 200 kW Phosphoric  
Acid Fuel Cell at Chugach in Anchorage



Ballard Automotive PEM Stack



EPYX  
Reformer



Avista Modular PEM Cell  
Stack



IdaCorp 5 kW RFC



Plug Power 5kW CHP RFC  
Ft Jackson Columbia, SC



# RFC Installation Photos Ft Jackson, SC



RFC on its Pad. Inspecting Reformer



Customer Side  
Thermal Recovery Piping

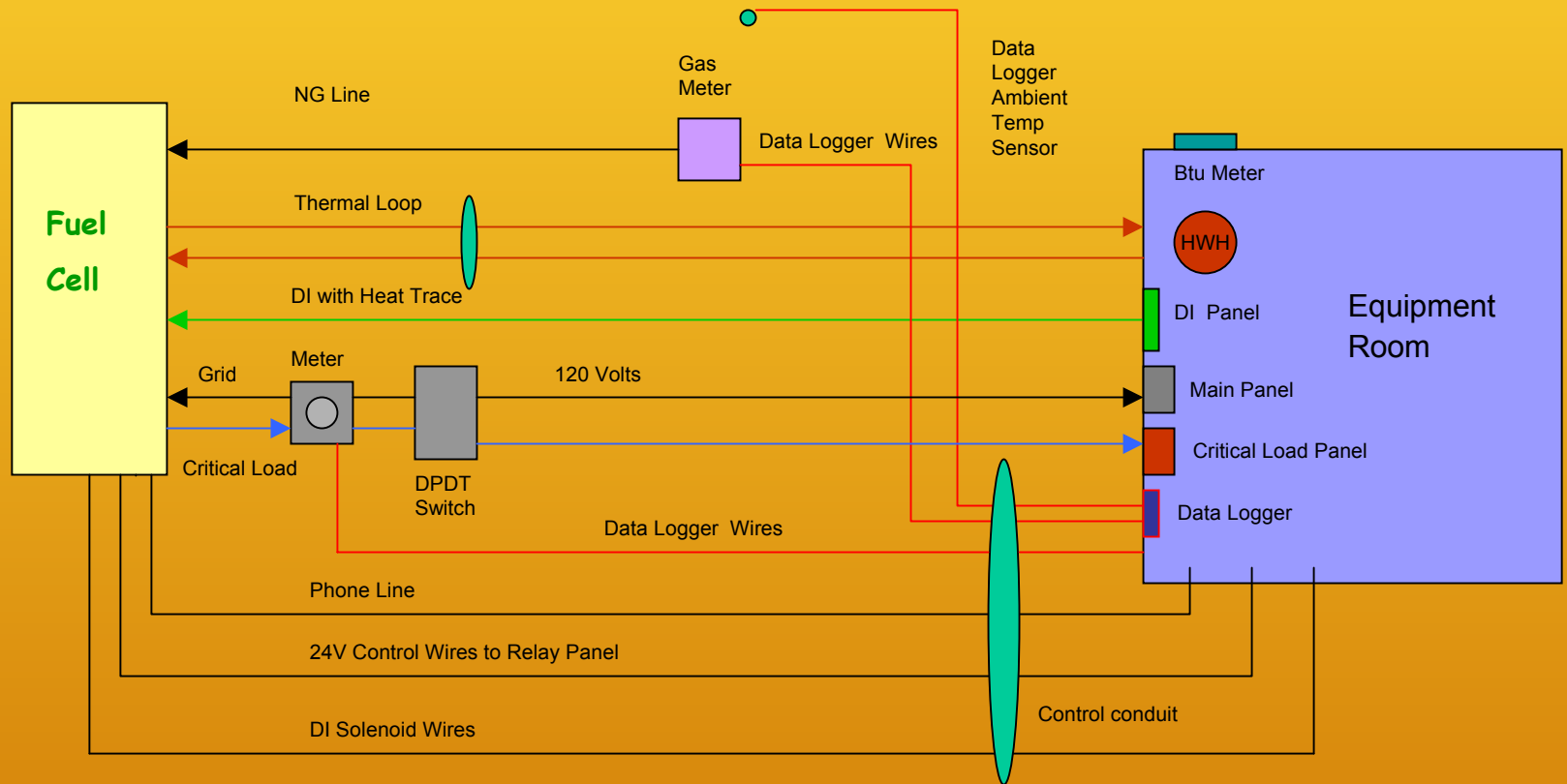


RFC Customer Interface



Inverter Cabinet

# RFC One-Line with CHP



## Benefits...

### Summary

- Fuel Cell Power can be sized to accommodate different capacity needs by paralleling multiple units. Flexible siting.
- High conversion efficiency relatively independent of system capacity.
- Environmentally benign energy service due to low emissions. Reliable, clean, and quiet.
- Electrochemical conversion process, dynamic power response, few moving parts... means low maintenance and operating costs.
- Conversion efficiency with cogeneration may exceed 85%.

## Industry Issues...

### Technology Perspective

- To promote the advantages of fuel cell technology in support of mission critical electrical loads in government and commercial applications.
- To promote the advantages of fuel cell technology in energy efficiency and conservation at home and at commercial facilities with combined heat and power.
- To demonstrate how fuel cell installations may eliminate the need for motor generators, battery banks and stand-by generators at commercial facilities.
- To promote the advantages of fuel cell technology in supporting the "clean" and "premium power" requirements of client facilities.
- To demonstrate the commitment of US business in promoting national air quality policies with "Green Power" from fuel cell power generation.
- To promote fuel cell technology into widespread Federal Government applications.
- To leverage the purchasing power and market pull of the Federal Agencies to reduce manufacturing costs, and assist fuel cell market expansion across the broader national economy.

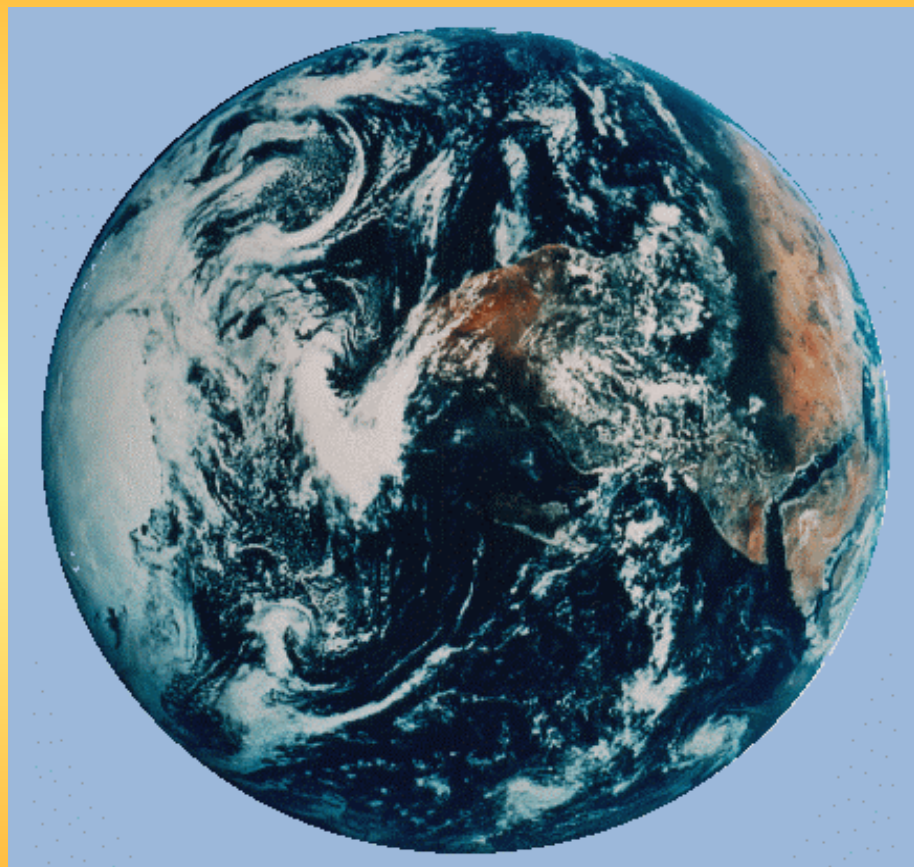


## Growth Issues...

### Market Prospective

- Growing product awareness and user acceptance.
- Maturing "green" technology with enviable service record.
- Fast pace growth and utilization of power sensitive electronic technologies in government and business sectors.
- Increased demand for "premium" uninterruptible energy service.
- Restructuring of power industry creating specialized energy service requirements. Change does not signal improvement...Recent IBM survey!
- Early adopter markets exhausted, industry needs new blood!
- Relative high initial cost rapidly falling (35% since 1992) \$4200/kW today, projected \$1750/kW by 2005.

Thank You...



*It's Your World,  
Power It Wisely!*

**LOGANEnergy**

The Wise Power Choice  
[www.loganenergy.com](http://www.loganenergy.com)

*It's Your Power,  
Choose It Wisely!*